An Overview on Time-frequency Effects of ECG Signals Using Synchroextracting Transform

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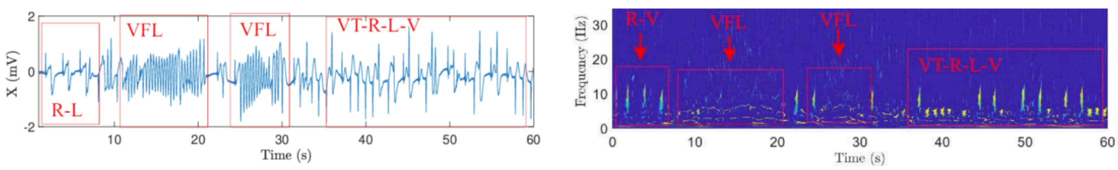
Abstract. Cardiac dysfunctions and arrhythmias are nonlinear and complex phenomena and can be monitored using electrocardiogram (ECG) recordings. ECG signals, and their underlying signal generation mechanisms, have strong nonlinear characteristics and in some cases, present rich dynamic responses. In this paper we aim to characterize the abnormalities found in patients with arrhythmias through a novel signal processing procedure applied to ECG signals, and by characterizing them in the time and frequency domains. Specifically, we propose use of the wavelet-based Synchroextracting transform (WSET), an emerging method for time-frequency analysis (TFA). The central idea of WSET is to increase the concentration of energy in the time-frequency representation (TFR), and capture variations of the instantaneous frequency (IF) of the original, weak signal, which enables better characterization of anomalies in the frequency domain. In this study, using a public arrythmia database, WSET is employed to extract nonlinear and complex features of pathologies present in the ECG signals, thus facilitating characterization and diagnosis of subtle anomalies in the patient's heart.

Introduction

Time-frequency analysis techniques (TFA), such as continuous wavelet transform (CWT), are very efficient in parameter / feature extraction, and solving the fixed window size problem of short time Fourier transform (STFT). Another problem encountered in TFA is the energy dispersion in the TFR which can hide/offset some frequencies, and causing inaccuracy in TFA. Methods based on synchrosqueezing try to mitigate this problem as presented in [1]. Emergent TFA techniques have been proposed in order to concentrate energy in the TFR, including the wavelet-based synchrosqueezing transform (WSST) and wavelet-based synchroextracting transform (WSET). A comprehensive discussion about synchroextracting transform (SET) formulation, with its applications and limitations, is presented in [1] In this work, WSET will be used, which is one of the emerging methods that has been used in the characterization of signals from mechanical systems [2]. It is important to note that these methods are eminently suitable for characterization of signals with nonstationary, nonlinear and chaotic characteristics. It is well-known that ECG signals are strongly nonlinear: the ECG signal in healthy conditions presents quasi-periodic responses, while a signal containing a pathological condition, in general, presents chaotic or quasi-periodic responses.

Time-frequency analysis using wavelet-based synchrosqueezing transform

Fig.1-a shows a time-domain ECG signal that contains 5 types of abnormalities: Right bundle branch block beat (R), Left bundle branch block beat (L), Premature ventricular contraction (V), Ventricular tachycardia (VT), Ventricular flutter (VFL). WSET scheme is used and are presented in Fig.1-b, it is possible to see how the method characterizes the instantaneous frequencies throughout the signal, allowing better temporal localization of a different clinical condition. We also observe discontinuities in the main frequency. Due to the concentration of energy in the TFR it is possible to observe the strong variation in the frequency spectrum at the instants when the cardiac arrhythmias occur, and this variation is a qualitative indicator of occurrence of period doubling, quasi-periodicity and routes to chaos in nonstationary signals, as described in [3].



(a) (b)

Figure 1: (a) ECG signal with several clinical conditions, and (b) Frequency domain response - WSET scheme.

References

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